# UNITED STATES PATENT APPLICATION

of

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for

# BALL LENS FOR USE WITH A DENTAL CURING LIGHT

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# BALL LENS FOR USE WITH A DENTAL CURING LIGHT

## BACKGROUND OF THE INVENTION

### 1. The Field of the Invention

**[0001]** The present invention relates to the field of dentistry, particularly to dental light curing devices used to cure light curable compositions used in dental restoratative procedures. More particularly, the invention is in the field of lenses that are attached to light curing devices and methods of use.

### 2. The Relevant Technology

**[0002]** Light curing devices are employed to polymerize and cure light curable compositions in a variety of industries. Light curing devices include a light source which emits light energy for curing a light curable composition. In the field of dentistry, for instance, light curing devices are often employed to polymerize and cure light curable compositions, such as light curable composites, adhesives, resins, and other polymerizable compositions containing photoinitiators.

**[0003]** By way of example, a light curable composite is often employed to fill a dental cavity preparation. Once the dental preparation has been cleaned and/or etched in preparation to filling, a layer of light curable composite is delivered to the area to be filled. Because the wavelengths used to cure the composition generally do not penetrate deeply, a series of thin layers are applied, curing each layer before applying the next.

**[0004]** In the course of placing filling material in between teeth, a matrix form, typically made of metal or plastic, is used. With resin restorations, it can be difficult to have the

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filling make tight contact with the adjacent tooth. Tight contacts are important or the patient will pack food debris in between the teeth. This is not only a nuisance, but can lead to further complications. Additionally, it is important that the contours between the teeth be anatomically correct, particularly with appropriate convexities. This is important to maintain healthy gum tissue below the contact area, but it is also important to support the biting surface of the filling correctly and prevent breakage of the filling.

**[0005]** In view of the foregoing, there is an ongoing need to provide improved apparatus and methods for fabricating and filling dental preparations.

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## BRIEF SUMMARY OF THE INVENTION

**[0006]** The present invention is directed to a ball lens to be used with a light-emitting device and related methods for filling a dental preparation with a light-curable filling material. The ball lens and related method allows a dental practitioner to establish a tight contact as each increment of resin filling material is constructed. At the same time, it allows the dental practitioner to develop an anatomically correct convexity in the proximal filling.

**[0007]** The ball lens includes a connector body configured to couple or attach to a light-emitting device, an elongate light guide extending from the connector body, and a light transmitting ball at an end of the light guide distal to the connector body. The connector body captures at least some of the light emitted by the light source of a light-emitting device during use. The ball lens allows a dental practitioner to hold a matrix band against an adjacent tooth prior to and/or while incrementally curing the light curable composition.

**[0008]** The lens may be integrally connected to a light-emitting device, or it may be configured to be removably attached to a light-emitting device so as to capture at least some of the light emitted by the light source of the light-emitting device. The type of connection between the ball lens and the light-emitting device may include a snap fit, a friction fit, a threaded fitting, a bayonet coupling, or other similar couplings.

**[0009]** In use, a layer of a light curable composition is applied to a dental preparation. The ball lens is used to hold a matrix band against an adjacent tooth prior to and/or while incrementally curing the composition. Additional layers of composition may be applied and cured while holding the matrix band against the adjacent tooth until the dental preparation is filled as desired. Using the ball lens to hold the matrix band against the adjacent tooth results in a filling making tight contact with the adjacent tooth while having an anatomically correct convexity.

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**[0010]** These and other advantages and features of the present invention will become more fully apparent from the following description and appended claims, or may be learned by the practice of the invention as set forth hereinafter.

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## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** To further clarify the above and other advantages and features of the present invention, a more particular description of the invention will be rendered by references to specific embodiments thereof, which are illustrated in the appended drawings. It is appreciated that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. The invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

**[0012]** Figures 1A-1C illustrate exemplary embodiments of ball lenses according to the invention;

**[0013]** Figures 2A-2C illustrate alternative elongate light guides and light-emitting balls that may be used in the lenses of Figures 1A-1C;

**[0014]** Figure 3 illustrates a lens attached to a dental light curing device;

**[0015]** Figures 4A-4D illustrate several exemplary fittings for removably attaching a lens according to the invention to a focusing lens attached to a light-emitting device.

**[0016]** Figures 5A-5C illustrate alternative dental light curing devices with a lens attached thereto; and

**[0017]** Figures 6A-6B illustrate a lens being inserted within a dental preparation.

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## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

### I. Introduction and Definitions

**[0018]** As used herein, the term "light-emitting device" includes any dental light device that generates light, whether using a bulb, plasma arc light, laser diode, an LED, a plurality of LEDs, or other light source. It also includes any dental device that emits (even though it may not generate) light, such as a fiber optic light guide. A "light-emitting device" may comprise all or part of a "dental curing light" or "device".

**[0019]** The term "footprint," as used herein, is generally made with reference to the cross-sectional shape of light emitted by a light-emitting device. The general shape and dimensions of a "footprint" of light can be identified by placing an object (*e.g.*, a generally flat object) in front of a light source and observing the size and shape of the area illuminated by the light source.

**[0020]** The ball lens of the present invention includes a connector body that couples or attaches to a dental curing light so as to capture at least some of the light emitted by the light source, a light guide extending from the connector body through which light captured by the connector body can be channeled or transmitted, and a light-emitting ball at an end of the light guide distal to the connector body through which light can be emitted.

### II. Exemplary Ball Lenses

**[0021]** Figure 1A illustrates an exemplary embodiment of a ball lens according to the present invention. Ball lens 10 includes a connector body 12, an elongate light guide 14 extending from the connector body 12, and a light-emitting ball 16 at an end of the light guide 14 distal to connector body 12. In addition, lens 10 includes an optional focusing lens 18 disposed within a hollow interior defined by body 12. The connector body 12 is configured to releasably attach the lens 10 to a light-emitting device 30. In the embodiment

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shown in Figure 1A, the lens 10 is actually attached to an intermediate focusing lens 19, which is itself attached (integrally or releasably) to the light-emitting device 30. It will be understood that the intermediate lens 19 is optional such that the lens 10 can be attached directly to the light-emitting device 30 by any desired attachment means (not shown) known in the art. For example, the ball lens 10 may be attached to light-emitting device 30 by means of a snap fit, a press fit, a friction fit, a threaded coupling, a bayonet coupling, or any other type of coupling. Alternatively, the connector body 12 may be integrally attached to the light-emitting device (or intermediate lens).

**[0022]** Also illustrated in Figure 1A is an array of two light sources 28, which are preferably light-emitting diodes (LEDs), but may include any kind of light source, including, for example, laser diodes, plasma arc lights, or various bulbs (such as halogen bulbs, incandescent bulbs, or fluorescent bulbs).

**[0023]** The connector body 12 may be opaque so as to block transmission of light energy through the connector body 12 so that curing light energy transmitted by the lens 10 has a pattern or footprint that is smaller than the footprint of light energy that would be emitted without an opaque connector body 12. Alternatively, the connector body 12 may be transparent so as to facilitate curing light being transmitted through the connector body 12.

**[0024]** The connector body 12 may have various configurations. The conical connector body 12 of Figure 1A is one exemplary configuration. Alternative conical configurations are illustrated in Figures 1B-1C. At least a portion of the connector body 12 may be flat. If all of it is flat, it will simply comprise a flat disk or disk-like structure (not shown) having an aperture through which the elongate light guide extends.

**[0025]** The elongate light guide 14 extends from connector body 12 and is transparent or translucent to curing light energy, which allows it pass through and be transmitted by light

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guide 14. Elongate light guide 14 may be hard or somewhat flexible, as desired. The elongate light guide 14 (along with the connector body, ball, and any optional focusing lenses) may comprise any desired transparent or translucent material. According to one embodiment it may be formed of acrylic, polyacrylic, polycarbonate, silicone, aluminum dioxide, sapphire, quartz, or glass. According to another embodiment, it may be formed of urethane, polyurethane, silicone, polyethylene, or any other material with suitable transmission characteristics with respect to curing light energy.

**[0026]** Lens 10 may also include one or more focusing lenses, such as focusing lens 18. The curing device shown in Figure 1A also includes an intermediate lens 19 for focusing light before entering the ball lens 10. Focusing lens 19 helps to collimate the light that is emitted from the light-emitting device 30. Exemplary focusing lenses for use in focusing light energy emitted by a plurality of LEDs are described in detail in U.S. application Serial No. 10/044,346, the disclosure of which is hereby incorporated by reference. After passing through lens 19, the light enters focusing lens 18 and is further collimated before exiting out of the ball lens 10 through elongate light guide 14 and light-emitting ball 16. Lenses 18 and 19 are optional, and the space they occupy in Figure 1A could alternately be empty, allowing the curing light energy to simply enter lens 10 through the end coupled to light-emitting device 30 and exit through elongate light guide 14 and ball 16. If present, focusing lenses 18, 19, or other such lenses may be formed of any transparent material known and used in the art, such as glass or plastic.

**[0027]** According to one embodiment, the ball has a diameter ranging from about 1 mm to about 6 mm, and more preferably from about 2 mm to about 4 mm.

**[0028]** Figures 2A-2C illustrate a number of exemplary focusing lenses 18, elongate light guides 14, and light-emitting balls 16 having varying configurations. Each focusing lens,

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elongate light guide, and ball may be formed together as one integral piece, or may comprise separate pieces. Figure 2A illustrates a focusing lens 18 and an elongate light guide 14a that has a tapered configuration. A light-emitting ball 16 is a disposed at the end of the tapered elongate light guide 14a. Figure 2B illustrates a focusing lens 18, an elongate light guide 14b, and a light-emitting ball 16b disposed at the end of the elongate light guide 14b. Ball 16b has a diameter substantially equal to the diameter of cylindrical elongate light guide 14b. Figure 2C illustrates a focusing lens 18, a tapered elongate light guide 14c, and a ball 16c disposed at the end of the tapered elongate light guide 14c. Ball 16c has a diameter substantially equal to the end diameter of tapered elongate light guide 14c.

**[0029]** Figure 3 illustrates one embodiment of a dental curing device 34 with a ball lens 10 attached thereto. Exemplary dental curing lights are disclosed in U.S. application Serial No. 10/068,103, the disclosure of which is incorporated herein by reference. Dental curing device 34 has the general configuration of a standard dental hand piece. The shape of the body 36 is generally cylindrical, being defined by a circular cross-sectional shape. It will be appreciated, however, that the cross-sectional shape of the body 36 may be configured into other shapes, including, but not limited to, square, triangular, hexagonal, oval, rectilinear shapes, and combinations thereof. The body 36 may also include small or slight irregularities or protrusions such as protrusion 38, which may be configured with control buttons (not shown) for controlling the operation of the dental curing device 34. According to one embodiment, the dental light curing device also includes controls for controlling the intensity and/or duration of radiant energy from the light source.

**[0030]** The generally cylindrical shape of the body 36 enables a dental practitioner to comfortably hold the dental device 34 in various positions. The body 36 of the dental curing

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device 34 is also useful for enabling the dental practitioner to easily rotate and move the curing device 34 into various positions during a dental procedure.

**[0031]** As shown, the dental curing device 34 is also configured to be connected with a power cord 40 at a proximal end of the body 36. Although not shown, the power cord 40 operably connects the curing device 34 to a power supply (not shown) remotely located away from the curing device 34. The remote power supply may include an electrical wall receptacle, a battery pack, a generator, a transformer, or any other power supply suitably configured for providing an appropriate supply of power to the curing device 34 for illuminating the light source (not shown) of the curing device 34, which is disposed at the distal end of the dental device 34 under lens 10.

**[0032]** In one embodiment, the light source may include an LED configured to emit radiant energy that is suitable for curing light curable compositions. It will be appreciated, however, that a preferred light source may also include an LED array, a plurality of LEDs, or other light sources.

**[0033]** Lenses according to the invention may be attachable and detachable from the distal end of a light-emitting device using any known attachment means, such as with a snap fit, a friction fit, a press fit, a threaded coupling, a bayonet coupling, or any other type of coupling for enabling the lens or different types of lenses with different functionality to be interchangeably used with a light-emitting device according to need and preference.

**[0034]** Several exemplary fittings between the connector body 12 and optional focusing lens 19 are illustrated in figures 4A-4D. These same fittings could be used anywhere a detachable connection is desired (e.g. between focusing lens 19 and a light-emitting device, or between connector body 12 and a light-emitting device). Figure 4A illustrates a snap fit arrangement. Focusing lens 19 includes a recess configured to retain a corresponding

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protrusion in connector body 12 in a snap-fit arrangement. Figure 4B illustrates a friction or compression fit. Connector body 12 includes a recess configured to tightly receive a corresponding protrusion formed in focusing lens 19. Figure 4C illustrates a threaded coupling. Connector body 12 and focusing lens 19 include corresponding grooves and raised threads, which raised threads are received in the corresponding grooves to threadably connect body 12 to focusing lens 19. Figure 4D illustrates a bayonet coupling. Focusing lens 19 includes a recess configured to accept a corresponding protrusion formed in connector body 12. Alternatively, the lens may be integrally attached to either the lens 19 or a light-emitting device by, *e.g.*, adhesive, welding, or other non-removable coupling.

**[0035]** Figure 5A illustrates an alternative dental light curing device 46 with a lens 10 attached thereto. Light curing device 46 is comprised of a body 48 coupled to a power source (not shown) by an electrical cord 50. Device 46 includes a trigger 52 or other activator to operate the device. The distal end of device 46 may include a light source (not shown) and corresponding structure configured to couple with lens 10. Light curing device 46 may use any kind of single or multiple light sources, including halogen bulbs, incandescent bulbs, fluorescent bulbs, laser sources, plasma arc lights, or light-emitting diodes (LEDs).

**[0036]** Lens 10 may be detachable from the distal end of the dental light curing device 46, such as with a snap fit, a friction fit, a threaded coupling, a bayonet coupling, or any other type of coupling for enabling the lens or different types of lenses with different functionality to be interchangeably used with the dental device 46 according to need and preference. Alternatively, the lens 10 may be integral with the distal end of the dental device 46, such as with an adhesive, by welding, or with other non-removable coupling.

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**[0037]** Figure 5B illustrates a light curing system 70 comprising a light-emitting device 72 that includes a curved fiber optic light guide 74 configured so as to capture and transmit light generated by a light source (not shown) disposed within the light-emitting device 72. A lens 10 according to the invention is attached to a distal end of the fiber optic light guide 74, which comprises a "light-emitting device".

**[0038]** Figure 5C illustrates a light curing system 70′ comprising a light-emitting device 72 that includes a curved fiber optic light guide 74 configured so as to capture and transmit light generated by a light source (not shown) disposed within the light-emitting device 72. An alternative embodiment of a lens 10′ having an elongate light guide 14' having a bend is attached to the distal end of the fiber optic light guide 74. An elongate light guide 14' having a bend may be useful and provide added convenience for working in hard-to-reach places, *e.g.*, the back side of a tooth whose back side is not readily accessed using a lens with a straight elongate light guide.

**[0039]** The elongate light guide 14 can have any desired length, with lengths of 4-20 mm being preferred and lengths of 8-15 mm being more preferred. In one embodiment, the overall length of the elongate light guide 14′ according to the invention is 11 mm overall, and 8 mm from the aperture of the connector body 12 from which the elongate light guide 14′ extends to the bend.

## III. Exemplary Method of Use

**[0040]** Figure 6A illustrates a lens 10 being used during filling of a dental preparation 80 of a tooth 82. The dental preparation 80 may represent any dental preparation, as known by those skilled in the art. As shown, the dental preparation 80 and tooth 82 may be surrounded by a matrix band 84 that may be used for providing form when filling the dental preparation 80. Matrix bands are well known to those of skill in the art. As shown, a layer of a light

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curable composition 86 is applied to the bottom of dental preparation 80. The elongate light guide 14 and ball 16 are sufficiently narrow so as to be insertable into the dental preparation 80. The dental practitioner may use the ball 16 to hold the matrix band 84 against the adjacent tooth prior to and/or while curing the layer of light curable composition 86.

**[0041]** To minimize problems associated with polymerization shrinkage, light curable compositions may be applied in layers of about 2 mm or less. For deep dental preparations, a layer of composition 86 may be applied, the ball 16 may be used to hold the matrix band 84 against the adjacent tooth prior to and/or while curing the layer of light curable composition 86, and then a subsequent layer of light curable composition 88 may be applied. The ball 16 may be used to hold the matrix band 84 against the adjacent tooth while curing the layer of light curable composition 88 in the same manner, as illustrated in Figure 6B. Additional layers of light curable composition are applied and cured in the same manner until the dental preparation 80 has been filled. Using the ball lens 16 to hold the matrix band 84 against the adjacent tooth results in a filling making tight contact with the adjacent tooth while having an anatomically correct convexity.

**[0042]** The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

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